A Hybrid Framework for ERP Preprocessing in EEG Experiments

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INTRODUCTION

The increasing complexity of the methods used to derive information from EEG signals requires the input data to be as artifact-free as possible to avoid interpretation bias. However, common preprocessing algorithms using single method struggle to reduce several types of artifacts/noises while preserving neural information.

AIM

The proposed framework aims to provide a standard to preprocess a wide range of Event-Related Potential (**ERP**) signals as required to improve the accuracy of further inference on neural processes.

This **hybrid** pipeline combines multiple state-of-the-art preprocessing approaches to reduce **specific types of artifact** without affecting useful parts of the signal.

METHOD

Our framework is composed of 8 preprocessing steps following good practice recommendations from OHBM COBIDAS MEEG committee[1]:

- Bad channel removal (visual inspection)
- **Ocular** artifact rejection using a **Multichannel Wiener Filter**[2] applied on blinking artifacts and eye movements
- Detrending, demeaning and low pass filtering (4th order Butterworth, 200Hz)
- Data epoching around the stimuli appearance (from 500ms before to 1000ms after stimulus onset) and downsampling to 512 Hz
- **Power line** noise reduction using the **Zapline**[3] algorithm
- **Muscle** artifact removal using a combination of Ensemble Empirical Mode Decomposition (EEMD) and Canonical Component Analysis (CCA) using the **ReMAE**[4] toolbox
- Baseline correction with a window spanning from 500ms to 200ms before stimulus onset
- Signal re-referencing to common average

All the codes are freely accessible at:
https://github.com/numediart/PreprocEEG

RESULTS

The proposed method has been validated on pseudo-data simulating the EEG signal corresponding to noisy ERP response[5] as described on Figure 1. The quantitative evaluation is done using the normalized root-mean-square error (NRMSE) to estimate the reconstruction accuracy and the Pearson correlation coefficient (PCC) to measure the covariance between the preprocessed and the ground-truth signals. Figure 2 shows a significant difference ($p<0.001$) on both the NRMSE and the PCC between the control and both preprocessed signals. The signals obtained using our framework exhibit an NRMSE significantly lower than those derived from the ICA-based method ($p<0.001$). However, ICA-based method reaches a weakly higher PCC than our framework ($p<0.05$). Figures 3 and 4 show an example of an EEG trial polluted by an eye movement and a muscle artifact, respectively.

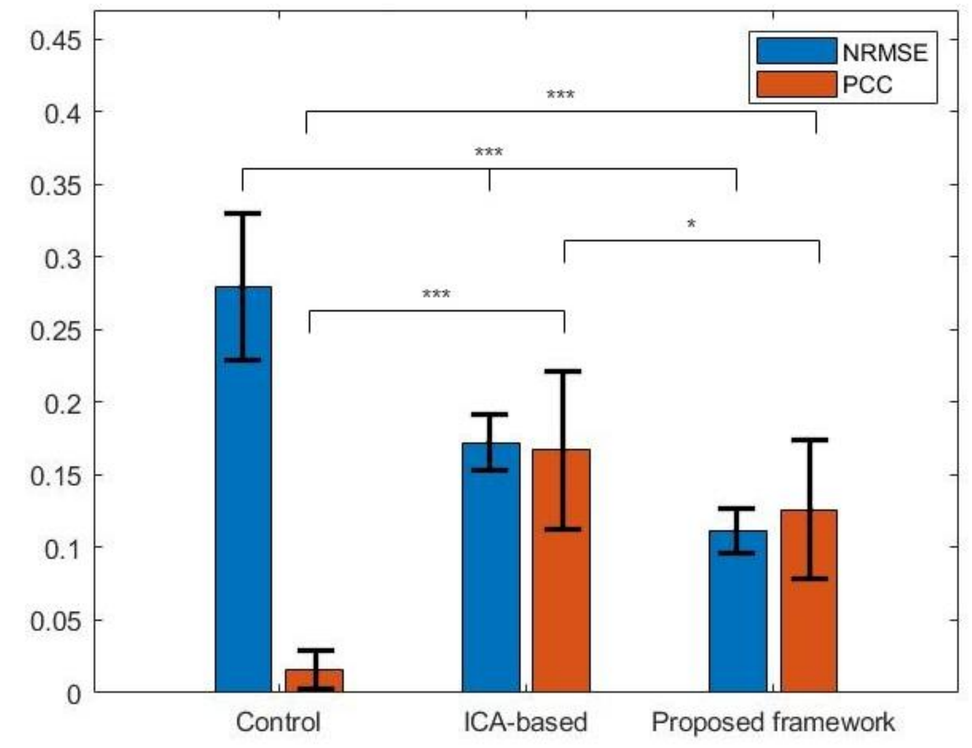

*Figure 2: **Quantitative evaluation** of the reconstructed signal. **NRMSE** and **PCC** computed between the ground truth simulated signals and the preprocessed ones (set of 20 simulated sessions with a SNR of 2 lasting 15 min each)*

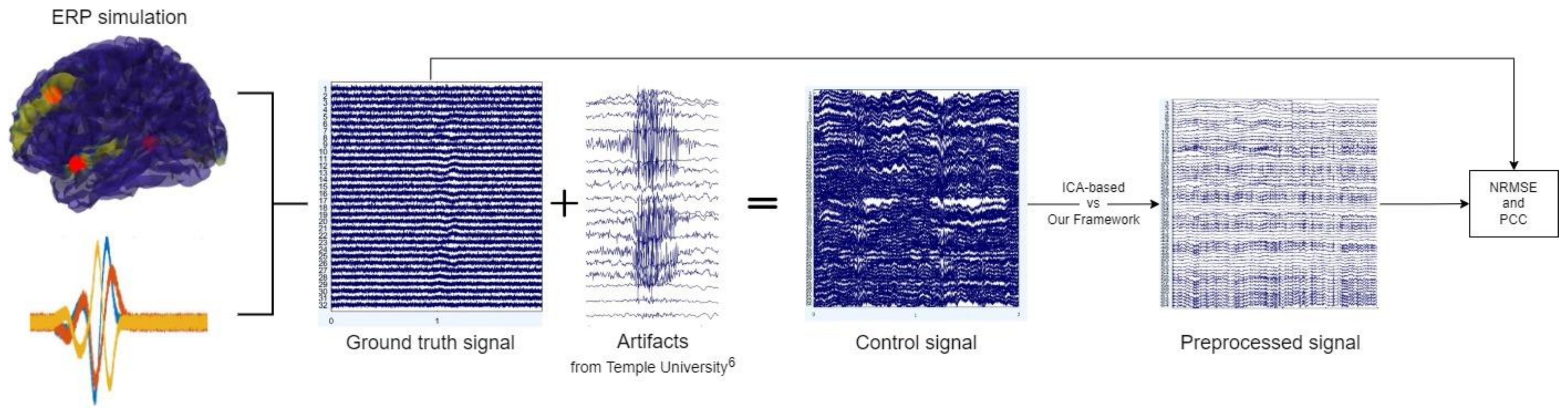

*Figure 1: **Validation process**. The simulated ERPs are generated at source level, then translated to pseudo-EEG signal used as ground truth, the addition of noise and artifacts from the Temple University database[6] leads to the control signal to preprocess. Having applied the studied preprocessing methods, the preprocess signal is evaluated using NRMSE and PCC*

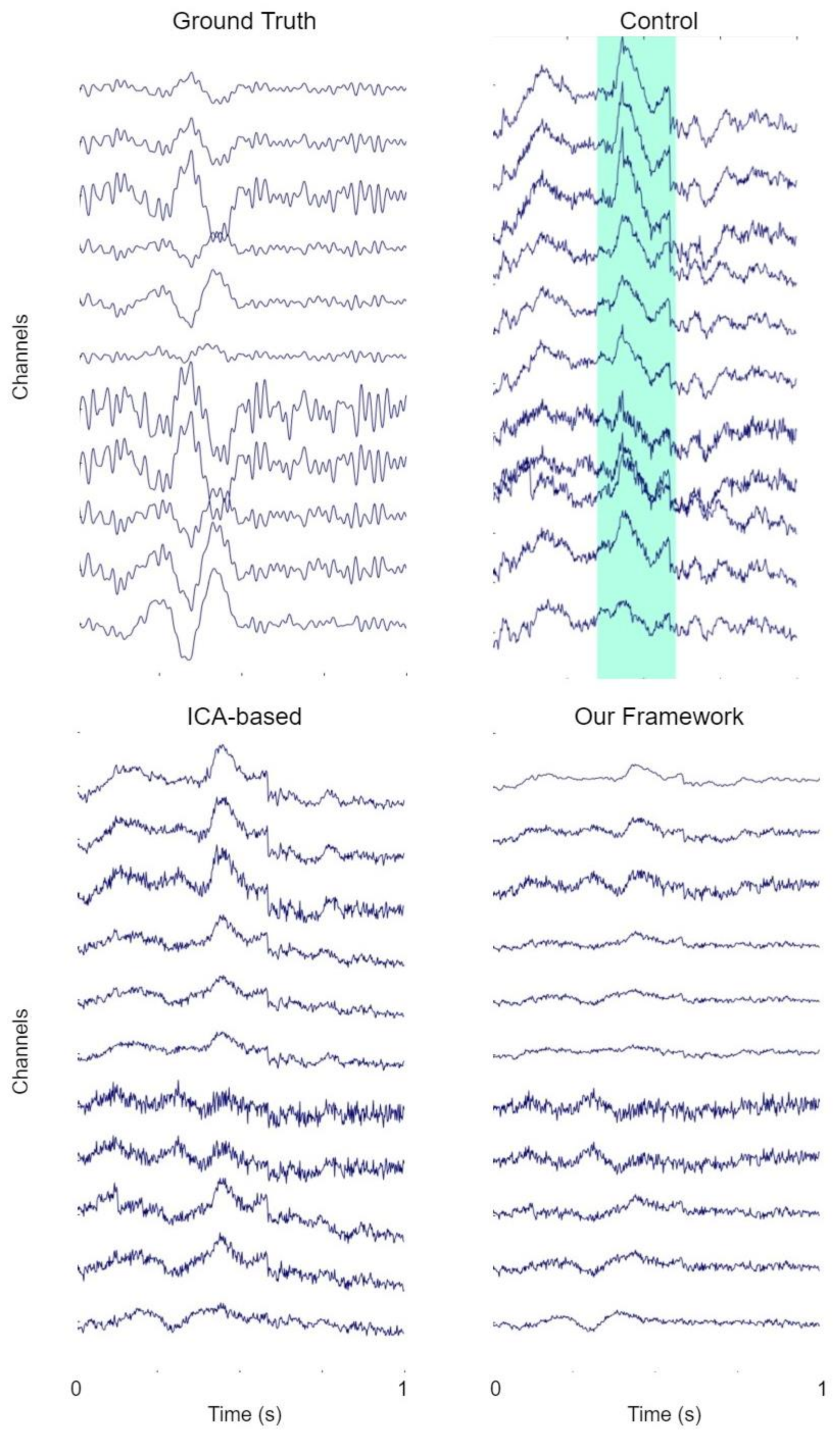

*Figure 3: **Qualitative evaluation** of a reconstructed signal polluted by an **eye movement artifact** (green region).*

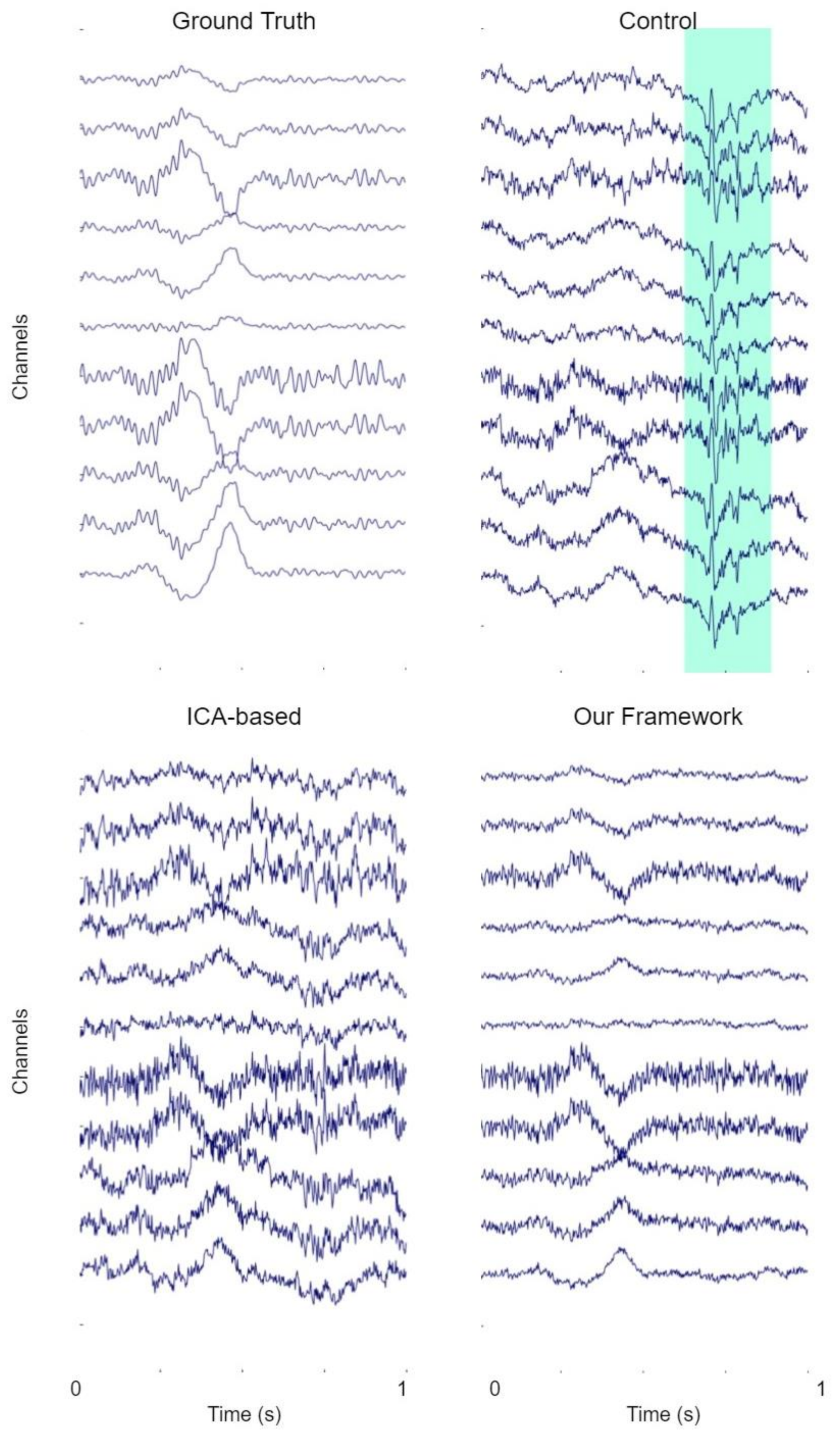

*Figure 4: **Qualitative evaluation** of a reconstructed signal polluted by a **muscle artifact** (green region).*

CONCLUSIONS

We propose a hybrid framework for ERP preprocessing showing high ability to reduce specific EEG artifacts, such as eye movement and muscle artifacts.
On simulated ERP data, the error (NRMSE) between the ground-truth data and the preprocessed signal is significantly reduced when using our method compared to common ICA-based framework.
We encourage researchers to use our freely accessible and modular codes to provide cleaner inputs to their next EEG studies.

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